2nd Symposium on Underwater Bio-Sonar Systems and Bioacoustics

23/24 July 2001
Burleigh Court Conference Centre, Loughborough University, Loughborough, Leicestershire, UK

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GOALS AND OBJECTIVES

We can learn much from the many examples of sophisticated acoustic systems where evolution has shaped the biological sensory system to achieve performance in excess of that obtainable by conventional signal processing. It is over 2 years since our previous conference on this theme, and a review of new developments in the field was becoming overdue.

The purpose of this conference was to review the present state of this continually evolving subject and to report on new developments and future trends. Particular themes of the conference included, but were not restricted to

- Sound production and reception mechanisms in marine organisms
- Impacts of underwater sound - environmental assessment
- Data capture systems for the localisation and classification of natural underwater sound sources
- Performance evaluation of biological sonars
- Classification and analysis techniques for bioacoustic signals
- Problems and mitigation of shipstrike - collisions between marine animals and ships and boats

EXECUTIVE SUMMARY OF SCIENTIFIC / TECHNICAL RESULTS

1 Environmental Impacts of Man-Made Sound

The conference opened with a Keynote paper by Tony Heathershaw from the Southampton Oceanography Centre on the environmental impact of underwater sound. This is an area that is growing in importance as more and more nations introduce legislation relating to noise generating activities in their waters. The paper described a method for assessing acoustic impacts that brings together the frequency, intensity and time domain aspects of the problem. It was clear, however, that most of the parameters required by the model are unknown in many cases of interest, so values based on experience and guesswork have to be used. An especially problematic area is the sensitivity of hearing of fish and marine mammals. Obviously there is much research still needed before legislation can seriously claim effective management of acoustic impacts in the marine environment.

The following session continued the theme, and was about auditory sensitivity and sound production in fish. Although the main topic was clearly of significance to the question of environmental impact, some of the secondary topics such as the signal processing used were also interesting. In particular, the paper by Tony Hawkins of the FRS Marine Laboratory, Aberdeen, described how wavelet analysis applied to recordings of sounds generated by fish in the sea was not only capable of discriminating between different species, but between individuals of the same species, even in a noisy environment with many signals overlapping.

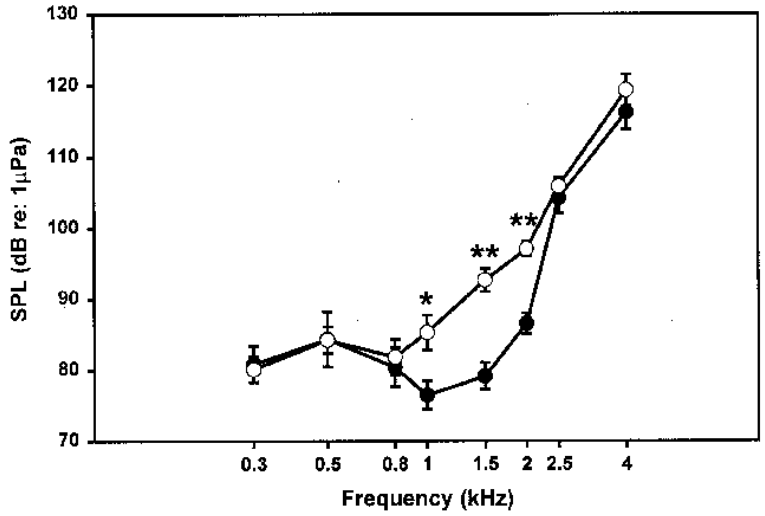

Fig. 1 Audiogram of fathead minnow showing threshold shift due to boat noise exposure (from Scholik et al, 'Effects of Underwater Noise on Auditory Sensitivity of Fish').

The other major contributor on the environmental impact topic was the second invited speaker, Bob Gisiner of ONR. Later on in the first day he described ONR's Effects of Sound on the Marine Environment (ESME) programme. This had much in common with the work described by Tony Heathershaw, and the declared target is a fusion of state-of-the-art databases and modelling algorithms that will give a quantitative estimate of the number of marine animals that might be killed or injured or exhibit adverse behavioural response, and the number of animals that might be unaffected by a given sound source. ESME could then be used to explore the benefits of operating the sound source in different locations, altering the operating properties of the source, or employing other impact mitigating actions.

Also related to the environmental theme was the AB Wood Medal Lecture. This medal is presented annually by the Institute of Acoustics and the Acoustical Society of America for significant contributions to the science of underwater acoustics. On this occasion it went to John Colosi of the Woods Hole Oceanographic Institution, principally for his work on the Acoustic Thermometry of Ocean Climate (ATOC) programme.

The ATOC programme is of interest from two points of view, apart from its principle purpose of monitoring the effects of global warming. Firstly, it has clearly demonstrated that by appropriate choices of signal types and processing techniques, sound can reliably be detected over propagation ranges of several thousand miles. Secondly, the programme has been severely disrupted, and actually stopped on several occasions, because of misguided concerns over the impact of the sound sources on marine mammals brought about by misunderstanding of the nature of underwater sound. It is because such political lobbying can be so effective, even when founded on false beliefs, that proper environmental impact assessment is essential.

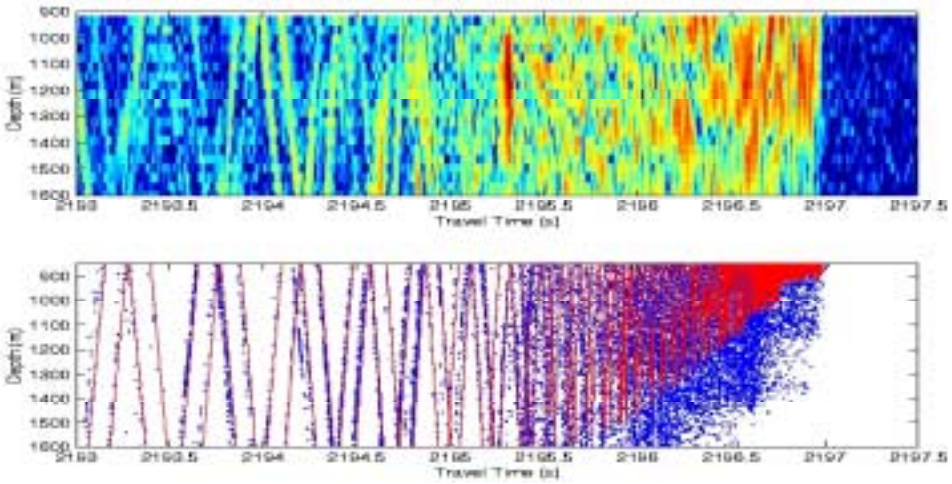

Fig.2 A measured pulse from a 3252km transmission (upper) and ray simulation calculations with (blue dots) and without (red) internal waves (lower) (from Colosi, 'A Scintillating Problem: Basin Scale Acoustic Propagation').

2 Signal Processing and Analysis

Another major theme of the conference was signal processing. This covered theories, models and experiments relating to the processing capabilities of various marine mammals and digital signal processing and analysis algorithms targeted on bio-like signals.

The first of these papers was by Laurie Linnett of Fortkey Ltd., Edinburgh. This was primarily about an extension to Fourier theory that decomposed a signal into a series of chirps each with its own different values for parameters such as amplitude, start time, start frequency and frequency rate. This is a useful analysis tool for transient signals, akin to the Fourier transform for stationary signals. In addition, it is a neat way of dealing with a signal contaminated with reverberation or multiple reflections allowing each reflected signal to be isolated and removed from the data.

Other signal analysis papers were presented by Gianni Pavan of University of Pavia, Italy, on a real time Windows based Digital Signal Processing Workstation (DSPW) targeted at biological signals, and Daryl Newborough of Loughborough University who described an Electronic Click Detection (ECD) system. The approach treats dolphin echolocation clicks as combined amplitude and frequency

modulated signals, and the developed circuit board acts as a demodulator giving the waveform envelope as an output that is easily handled by conventional audio recording and reproduction equipment.

Several papers describing the results of experiments on the signal processing performance of dolphins and porpoises were given by authors from former Soviet countries and from Israel. These covered target classification, determination of range, velocity and acceleration of moving targets, discrimination between slightly different clicks and temporal resolution. As always, the experiments demonstrated that the animals' capabilities in all these areas were superior to anything achieved to date with man-made sonars, although, contrary to the slightly confused musings of the biologists involved, nothing was demonstrated that exceeded the limitations of conventional communication theory. The principal authors in this area were Genadi Zaslavskiy from the Israeli University Authority for Applied Research and Tengiz Zorikov of the Georgian Academy of Science.

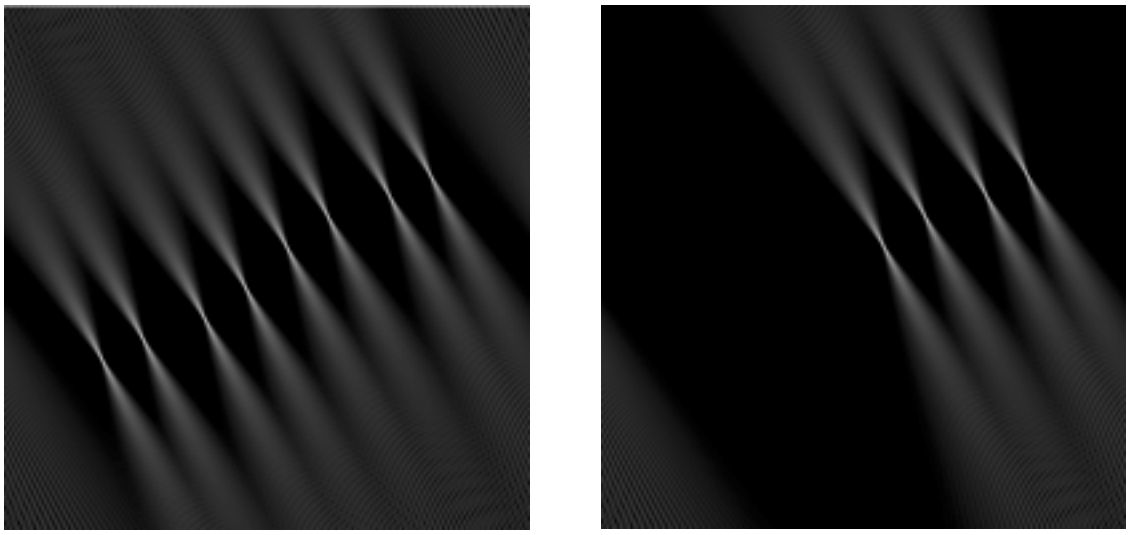

Fig.3 Fourier Extension Images of the real (left), and analytic (right) signals (from Linnett et al, 'Analysis of Linear Chirp Signals').

3 Target Localisation and Tracking

Angular discrimination of less than a degree and temporal resolution of about ten microseconds have repeatedly been demonstrated for dolphins, killer whales and porpoises, despite the fact that their echolocation clicks are typically 100 microseconds long and receiving beamwidths are in the order of ten degrees. In addition, these animals are known to be able to track and home in on a single target in a closely spaced mass of superficially similar targets.

As suggested above, most biologists working in the field regard these capabilities as black magic because they fail to understand the physics. However, the paper by Peter Dobbins of BAE SYSTEMS on localisation and one by Prof. Bryan Woodward of Loughborough University both show that such performance is quite feasible with the hardware and processing capabilities these animals are known to posses. The misunderstanding about angular localisation arises because of a failure to comprehend the meaning of the term resolution, and it is generally not understood that the reason why man-made

systems cannot compete is in part at least a matter of technology - we have not yet managed to make underwater acoustic transducers that operate in the required frequency range with adequate bandwidth.

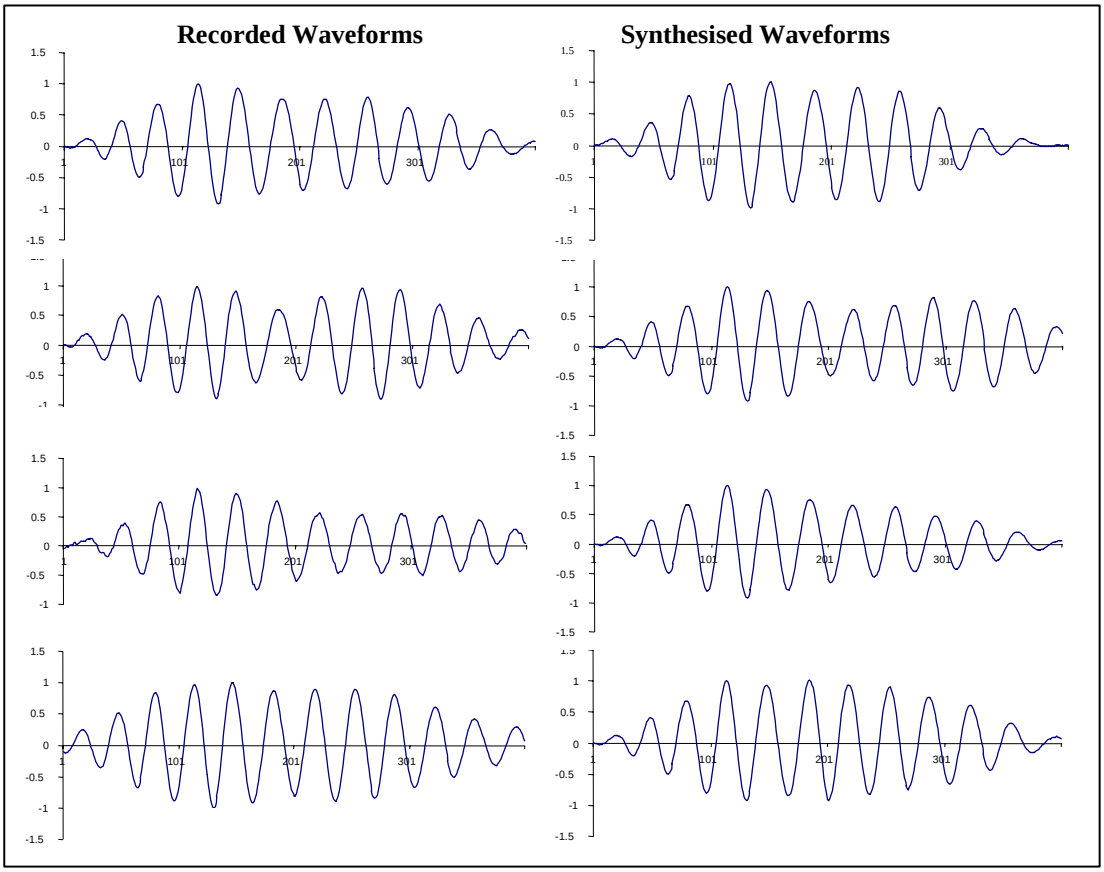

Fig.4 Comparison between synthesised and recorded waveforms for the Harbour Porpoise (from Goodson et al, 'Harbour Porpoise Echolocation Signal Components).

4 Sound Reception and Transmission Models

The last main topic of the conference was about the way various animals (specifically dolphins, porpoises and the sperm whale) transmit and receive sound. There is general agreement about the main principles of the way sounds are generated, although much argument about the details. The jury is still out, however, on reception mechanisms.

Transmission (for echolocation - audible communication sounds are produced in much the same way as in land-based mammals) is generally thought to originate from "lips" connected to the blow-hole which initiate impulses in the same way as blowing a "raspberry". In most species there are two sets of lips, and their operation is synchronised, although the way this works is a subject for debate. By varying the phase between the two sets of lips, the spectrum of the transmitted signal can be modified.

The impulse from the lips is coupled into a lens or waveguide forming the bulbous forehead in most species - and most of the head in the sperm whale. From here it emerges into the water, usually as a

plane wave with very well controlled directivity, and potentially at levels close to the cavitation limit. Ted Cranford presented a remarkable animation of all this happening in a sperm whale, although the bulk of his talk was about dolphins.

Reception is now generally acknowledged to involve the jaws, although there are still some biologists refusing to understand the acoustics. The main discussion is about whether sound is coupled through the jawbone into the inner ear, or whether the teeth actually act as transducers and pass signals via the mandibular nerves to the central nervous system.

The papers presented here did not throw much new light on the argument, except that John Potter and Elizabeth Taylor did identify brainstem cell groups in the auditory cortex potentially capable of generating appropriate time delays to correctly phase dental nerve signals to create an endfire beamformer.

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Summary of participants funded by ONRIFO.

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Mr S Vargas	Los Andes University	Colombia
Dr T Zorikov	Georgian Academy of Sciencies	Georgia

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Scientific Steering and Organizing Committee Members.

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Ed Harland	DERA (now QinetiQ)	UK

SPONSOR INFORMATION

List of all conference sponsors.

Agency	Country
Institute of Acoustics	UK
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PROCEEDINGS

Proceedings of the Institute of Acoustics, Volume 23 Part 4, 2001
ISSN 0309 - 8117, ISBN 1-901656-37-3
Obtainable from:
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SCIENTIFIC PROGRAM

2nd IOA Symposium on Underwater Bio-Sonar Systems and Bioacoustics
List of Papers

B. Woodward and N. Morphett • University of Loughborough, UK

Session 11: Signal Analysis (Part 2)

22 THE CHARACTERISATION OF BIO-ACOUSTIC SIGNALS THROUGH TIME-FREQUENCY METHODS
P. White • ISVR, University of Southampton, UK

23 SOFTWARE AND HARDWARE SOUND ANALYSIS TOOLS FOR FIELD WORK
G. Pavan[1,2], M. Manghi[1], C. Fossati[1] • [1]Università di Pavia, Italy, [2]Dept. of Urban Science, Venice, Italy

Session 12: Data Capture

24 AUTOMATIC DETECTORS FOR THE ECHOLOCATION PULSES OF SMALL ODONTOCETES
E.J. Harland • DERA, Winfrith, UK

25 THE NEW GENERATION OF ELECTRONIC CLICK DETECTOR (ECD): THE DEVELOPMENT AND FIELD TRIALS PROGRAMME
D. Newborough, C. Blomqvist, P.A. Lwpper and A.D. Goodson • Loughborough University, UK

COUNTRIES REPRESENTED AND NUMBER OF PARTICIPANTS

List of countries participating.

Country (total = 11)	**Number of Participants (total = 38)**
Colombia	1
Georgia	1
Germany	1
Israel	1
Italy	1
Japan	1
Russia	2
Sweden	1
UK	21
USA	6
Singapore	2

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